IDENTIFICATION AND CATEGORIZATION
OF FOREST INVESTMENT COSTS:
A FOREST ROAD CASE

Identification and Categorization of Forest Investment Costs: A Forest Road Case

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ABSTRACT

The National Forest Road and Trails Act of 1964 requires the Forest Service to allocate costs. The first logical step is to separate joint costs from non-joint costs before any arbitrary cost allocation is done. This study develops a technique that identifies and categorizes the costs as either joint or non-joint, and defines reasons for their separation.

To test this technique, costs of four development roads in the U.S. Forest Service Northern Region: two collector and two local forest roads, were chosen. Individual road costs, e.g., culvert or excavation costs, were identified and categorized as joint or non-joint and linked to products and uses created by a forest road. An average of 80% of the forest road's total costs were categorized as joint and would require further arbitrary allocation, but an average of 20% could be directly allocated to specific products using cost categorization. A high percentage of joint costs are due to the Forest Service's multiple-use mandate and inflexible road building standards and policies.

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INTRODUCTION

The U.S.D.A. Forest Service must deal with the problems of multiple outputs and cost allocation in its multiple-use mission. The study's purpose and objectives are: 1) to improve the Forest Service's capability to analyze a complex production process; e.g., building a forest development road, by developing a procedure which identifies and categorizes costs, plus defines reasons for jointness and non-jointness; 2) to test the procedures using cost data from the three stages of forest road development; and 3) to evaluate the performance of the procedure in identifying and distinguishing between joint and non-joint investment costs, and the reasons for their separation.

This thesis is organized into four chapters and two appendixes. The first chapter, the introduction, defines the problem and restates the study's purpose and objectives. The second chapter describes the identification and categorization technique, defines the methodology of data collection and of the technique evaluation procedure, and gives an example of using the identification and categorization technique. The third chapter gives the results of using the identification and categorization technique. The final chapter contains the conclusions and recommendations. The first appendix contains the theory of

joint production, and the second appendix contains a critical review of two joint cost allocation techniques dealing with the allocation of joint production costs of a forest road.

PROBLEM STATEMENT

Resource utilization can result in single or multiple products, the later may be divided into two subsets: 1) non-joint products and 2) joint products. To be independent a change in the output of one product will not affect the production of the other. For example, beef and mutton are technically independent products of ranching to a degree. Increasing beef production does not affect the production of mutton. Joint products are technically dependent: a change in the production of one output will affect the other outputs (Henderson and Quandt, 1980). The classic example of joint products are beef and hides. A decision to increase the output of beef can not be separated from the production of hides. For a more complete discussion on the definitions of joint and non-joint products and costs, see Appendix A - Theory of Joint Production.

The U.S.D.A. Forest Service is required by public law to allocate production costs. The National Forest Roads and Trails Act of 1964 (P.L. 88-657) section 4, in the provision, states:

> That where roads of a higher standard than that needed in the harvesting and removal of the timber and other products covered by the particular sale are to be constructed, the purchaser of the national forest timber and other products shall not be required to bear that part of the cost necessary to meet such higher standards, and the Secretary (Secretary of Agriculture) is authorized to make such arrangements to this end as may be appropriate.

Cost allocation is the process of assigning a portion of the production costs, whether joint or non-joint production costs, to a given product, department or use (Federal Register, 1980). This assignment is necessarily done using an arbitrary joint cost allocation technique (Ungar, 1980; Henderson and Quandt, 1980; Alchian and Allan, 1977; Moriarty, 1975; and Herfindall and Kneese, 1974). Host (1973) presents a forestry example of joint cost allocation dealing with forest road costs. He concludes, "there is no perfect way to allocate road costs among all user groups." He also states: "Some arbitrariness is needed in order to present this method" confirming the theoretical inconsistency of joint cost allocation (Appendix B - Critique).

Currently, the Forest Service's preferred cost allocation technique is known as "Separable Cost/Remaining Benefit" (Federal Register, 1982). Separable costs for each purpose; i.e., a product or use in a plan, are defined as the reduction in the total plan's costs if that purpose were excluded from the plan; i.e., costs incurred specifically for that purpose (Federal Register, 1980). Joint costs are

the total plan's cost minus the sum of the separable costs. The remaining benefit for each purpose is defined as the amount by which the benefit for a purpose exceeds the separable cost for that purpose (Federal Register, 1980). The benefits for each purpose may be approximated by using the opportunity costs of producing the purpose singly. The Federal Register, 1980, states: "Joint costs may be allocated among purposes in proportion to remaining benefits." For example, if the remaining benefit of a purpose is 10% of the benefit, then 10% of the joint costs are allocated to that purpose. There are many serious problems with this joint cost allocation technique. Appendix B, Critique, contains a critical review of this technique that identifies and examines these problems.

The first step in cost allocation is to identify those costs which are incurred for a specific purpose (Federal Register, 1980). Because of the complex - multiple input multiple output - production processes, both joint and non-joint production costs are often lumped together and treated the same so that all costs wind up arbitrarily allocated. There is no need to arbitrarily allocate non-joint costs if a process can be developed to define production costs as either joint or non-joint. Cost categorization is the process of separating production costs into joint and non-joint costs plus identifying product(s) or use(s) corresponding to these costs. A closer

examination reveals categorization is the direct allocation of non-joint production costs. This study uses forest roads as examples to identify, demonstrate and evaluate the application of a cost identification and categorization technique to complex production processes.

The categorization system reduces the amount subject to arbitrary cost allocation. An average of 20% of the four example roads' total costs were directly allocated to specific products using cost categorization. On a single road, an average 65% of the road's total costs were directly allocated to specific products using cost categorization. In addition to identifying products and uses associated with the joint production costs, cost categorization also identified reasons for jointness: the multiple-use directive of the Forest Service and the Forest Service's policies on road standards.

LITERATURE REVIEW

The cost categorization approach used in this paper is new; therefore, I have found no previous references in the literature describing the logical first step in cost allocation. There are, however, numerous cost allocation techniques given in the literature, but this is not a study of cost allocation techniques. The literature does provide a theory of joint production which is important to

understand if dealing with a complex production process which produces both joint and non-joint products.

According to Henderson and Quandt (1980) joint products are those products that are distinguished on technical grounds and are technically dependent. This is supported by Alchian and Allen (1977) who state that joint products "are interdependent in supply; generally, more of one involves more (or less) of the other." Furthermore, most economists agree that non-arbitrary allocation of common or joint cost is impossible (Ungar, 1980; Henderson and Quandt, 1980; Silberberg, 1978; Alchian and Allen, 1977; Moriarty, 1975; and Herfindall and Kneese, 1974).

Alchian and Allen (1977) state: "Pricing and output decisions are independent of joint cost apportionment." Market prices are used to ration products between consumers of separate markets. Market prices are a function of demand and existing supply. Therefore, there is no allocation problem in setting market price. Output decisions are also independent of cost allocation: market price dictates if an output is produced. Production will occur only if the change in total revenue for the whole joint product's set is greater than or equal to the change in total cost for the same product set. When total costs are greater than total revenue, output production will cease and firms would leave the market in the long run. The long run is characterized by a period of time over which all inputs become variable.

In the short run, many inputs are fixed; e.g. plant size, and it might be extremely costly for the entrepreneur to leave the market (Nicholson, 1978). Therefore, there is no need to allocate joint costs to determine if a product's set should be produced.

Joint cost allocation is not necessary for marginal analysis. The producer increases joint production, either singly (for variable proportions) or jointly (for fixed proportions), then compares the change in total revenue from increased production to the change in total costs from the same increase. If the change in total revenue exceeds the change in total costs, then production will be expanded. Using a marginal timber land's example, Bowes and Krutilla (1979) argue

> There is no need to allocate costs in order to decide upon the marginality of land for particular uses. Optimal allocation to particular management strategies may be easily evaluated if sufficiently accurate information on the outputs and total costs of alternative strategies is available for each land subunit.

Alchian and Allen (1974) agree:

> Pricing and output decisions do not require that proportions of common costs of a common production input be assigned to the products that are jointly produced.

Joint or common cost allocation is not necessary for economic optimization decisions if a market price may be determined. The argument concerning the difference between private and social costs; i.e., costs of external effects not accounted for in private production (Seneca and Taussig,

1979) when determining the market prices, are beyond the scope of this study. Problems occur when a zero market price exists or the market is not utilized. Seneca and Taussig (1979) define a market as "the institution through which potential buyers and sellers of goods and services deal with each other in the process of exchange."

Market price is determined by the simultaneous solution of the supply curve and the demand curve. There is no need to allocate joint production costs to determine the supply curves using either the profit maximization model or cost minimization subject to output constraints problem (Appendix A - Theory). The demand curve does not deal with production. Therefore, if the demand curve may not be estimated, this is not a problem due to cost allocation. If the supply curve may not be estimated, there are efficiency problems. Boadway (1979) states:

> The concept of economic efficiency is derived directly from the Pareto principle. An efficient allocation of resources is defined as Pareto-optimal--it is not possible to make anyone better off without at the same time making someone else worse off.

Economic efficiency implies technological efficiency. To estimate the supply curves, using either the profit maximization model or cost minimization subject to output constraints problem, requires both economic and technological efficiency (Henderson and Quandt, 1980; and Silberberg, 1978).

OBJECTIVES

There are three main objectives of this study: 1) to develop a categorization technique, 2) to test the categorization technique, and 3) to evaluate the categorization technique. I will examine each objective beginning with the first.

The technique developed should perform three steps. First, identify the individual investment costs; e.g., $17,000 for installing a culvert. Second, the technique developed should be able to distinguish between joint and non-joint costs and products by providing a logical and systematic method to file the empirical data. The filing system should be unambiguous and the file headings should be clearly defined to identify the product(s) or use(s) associated with the joint or non-joint costs. Finally, the technique should define reasons for separating joint and non-joint costs.

To test the categorization technique, I gathered cost data on building forest roads from four national forests in Region 1: 1) the Clearwater, 2) the Idaho Panhandle, 3) the Lolo, and 4) the Nezperce, and other documentation concerning the road; e.g., the environmental analysis report (EAR) and the preliminary engineering report (PER). The EAR and PER will define the product(s) or use(s) and reasons for jointness and non-jointness. With this data, I showed how the categorization technique files costs according to

product(s) or use(s) and reasons for jointness and non-jointness.

I evaluated the technique's ability to perform each step: 1) identifying the individual investment costs, 2) discerning between joint and non-joint costs, and 3) defining reasons for separating costs between joint and non-joint costs. Each step will be evaluated using four criteria: 1) utility, 2) practicality, 3) complexity, and 4) cost verses the value of information. I used an ordinal scale from 1 to 3 to evaluate how each step of the categorization performed: 1 denotes greatest benefit or lowest cost. This evaluation will show each step performed and whether one should proceed to the next step of the categorization process. In addition, I evaluated the technique's ability to minimize the amount of costs discerned to be joint.

METHODOLOGY

THE HYPOTHESIS

Cost identification and categorization is the first logical step in the cost allocation process. The identification and categorization technique described should identify and distinguish joint from non-joint investment costs, and identify reasons for their separation. Cost identification and categorization should reduce the amount subject to arbitrary cost allocation by positively identifying costs as either joint or non-joint.

THE TECHNIQUE

Initially, I had examined six cost identification and categorization techniques: 1) production resources, 2) product, 3) cost definition, 4) expected use, 5) causal factor, and 6) U.S.D.A. Forest Service management codes. However, when I identified and categorized the costs of the four example roads, techniques 2 and 4 gave the same result, and techniques 3 and 5 gave the same result. In addition, techniques 2 through 5 categorized the same proportions of cost as either joint or non-joint and into the same products and uses. Therefore, I concluded that cost categorization

techniques 2 through 5 were simply varying intensities of a single approach. The evolved identification and categorization technique contains the important components of techniques 2 through 5.

Technique 1, production resource, was established as an introductory technique. This technique gathered all the pertinent information dealing with the road and assembled the data in a workable form. This technique was an important component of categorization, rather than as an independent technique.

Technique 6, U.S.D.A. Forest Service management codes proved to be useless for cost identification and categorization. Forest Service management codes are used to translate work plans and payments into accounting data. However, management codes are not uniform but forest specific and the data are usually aggregated and not project specific. Therefore, it is almost impossible a posteriori to trace a single project in the detail needed. This system is unable to focus on each specific investment cost; e.g., the cost of a culvert. The only way this system might work is if a project could be tracked completely through the three phases of the roading process. To accumulate the data would take approximately ten years. I believe the ability to track a road's costs as finely as needed is impossible given the present system. Therefore, technique 6 was dropped from the project.

The evolved technique involves three steps: 1) identifying the investment costs, 2) discerning between joint and non-joint costs, and 3) defining reasons for separating costs between joint and non-joint costs. I will briefly examine the three steps beginning with the first.

The first step involves identifying inputs on an item by item basis with their per unit or total costs. For example, the schedule of items gives a list of inputs used in the road construction and their corresponding per unit and/or total costs.

The second step involves discerning between joint and non-joint costs. This expands on the first step by matching investment costs with the type of product or resource served by the expenditure. If the investment cost involves joint products, the cost is discerned to be joint. Alston (1972) uses the acronym FOREST to represent all the renewable surface resources (products) under direct management control of the U.S.F.S. as legislated by the Multiple Use-Sustained Yield (MU-SY) Act of 1960. These resources (products) are fish and wildlife (F), outdoor recreation (O), range and forage (R), environmental amenities (E), soils and watershed (S), and timber (T). I added two more resources (products) to this list; i.e., administrative (A) and mining or minerals (M), and created a new acronym AMFOREST. The implicit connection between investment costs and resources (products) comes from output considerations specified in the

environmental analysis report (EAR) and the preliminary engineering report (PER).

The third step involves defining reasons for separating costs between joint and non-joint costs. I divided costs into five types based on the possible rationales for making a specific investment: constraint (c), discretion (d), mitigation (m), overhead (o), and production (p).[1] Separability refers to defining the rationale for determining the type of cost. In addition, separability helps identify if any possible technical relationship exists among probable joint products. Separable costs are those costs which may be uniquely described by a specific activity. For example, "Tc" defines the separable cost, in this case constraint, associated with the products timber (T). "Tcp" defines a nonseparable cost, in this case both constraint and production rationales, associated with the product timber. Joint products may have separable costs; e.g., TSc. If Tcp and Scm are joint products with mixed separation rationales, the joint separation rationale must be "cmp". Being joint products, the same separation rationales uniformly affect both products. If the separation rationales are defined as cp and cm, the products are not truly joint.

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[1]The glossary contains the definitions of these and other terms used in this thesis.

DATA BASE: FOREST SERVICE DEVELOPMENTAL ROADS

This study uses Forest Service developmental roads as examples of multiple input - multiple output production. Forest development roads are defined by section 106 of the Federal-Aid Highway Act of 1978 as "a forest road or trail under the jurisdiction of the Forest Service". The Forest Service Manual (FSM), 1982, Chapter 7710.51, identifies three categories of forest development roads: forest arterial, forest collector, and forest local roads.

Forest arterial roads provide service to large land areas and usually connect with public highways or other arterial roads to form an integrated network of primary travel routes. The location and standard are often determined by a demand for maximum mobility and travel efficiency rather than specific resource-management service. They are usually developed and operated for long-term land- and resource-management purposes and continual use.

Forest collector roads serve smaller land areas and are usually connected to an arterial or public highway. They collect traffic from forest local roads or terminal facilities; e.g., camp grounds. The location and standards are influenced by both long-term multi-resource needs, as well as travel efficiency. Collector roads may be operated for either constant or intermittent service, depending on land use- and resource-management objectives of the area.

Forest local roads connect terminal facilities with collector or arterials roads, or public highways. The location and standards are usually determined by requirements of a specific resource activity, rather than travel efficiency. Local roads may be developed and operated for either long- or short-term service.

When the forest road system is expanded, arterials are developed first at the national forest level, and most have already been built. Collector road planning follows with the development of an area transportation plan. This is usually done at the zone or forest supervisory office (SO) level. Lastly, local road planning is also done at the zone or SO level.

Forest road construction usually involves seven steps, once the initial planning has been completed:

1) Location of the road;
2) Preliminary survey;
3) Geometric criterion and design;
4) Cost estimation;
5) Road system plan approval;
6) Construction and inspection;
7) Operation and maintenance.

This study concentrated on forest local and collector roads. Collector roads usually serve a few resources and local roads usually serve a single resource (FSM, 1982).

Arterial roads usually serve a mix of resources (FSM, 1982). The use of arterial roads is too diverse for testing cost categorization because too many conflicts develop between uses. Also, most arterials have been built and the historical data base was not sufficient for this study.

Four criteria were used for selecting collector or local road examples: 1) the roads had multiple-use aspects; 2) the roads' data were well recorded and easily accessable for efficient collection; 3) the roads represented the desired developmental stage; and 4) the roads were chosen from forests near Moscow, Idaho to moderate travel expenses. Four national forests were visited: Clearwater, Idaho Panhandle, Lolo and the Nezperce. One road was selected from each national forest, and the same data collection procedure was used to collect the cost data for each forest.

For data collection purposes and for demonstration ease, I divided collector and local roads' developmental process into three major phases:

I) planning and design;

II) construction;

III) operation and maintenance.

I will cover the data collection of each phase separately.

Phase I, planning and design, is the evaluation process plus construction steps 1 through 5. I collected the preliminary engineering report (PER), the environmental analysis report (EAR), and documented design changes. The

cost of interdisciplinary (ID) team meetings, which made changes and additions to the PER and EAR, proved difficult to collect for two reasons: 1) the time involved to complete this task was too great, and 2) the data needed was not readily available.

To estimate the cost of the ID team members and organizational overhead, I used the Forest Service's Program Accounting and Management Attainment Reporting System (PAMAR).[2] The PAMAR accounting system contains an aggregation of all the forests' activities including forest road building. These activities are translated into management information handbook (MIH) codes and recorded at the regional office level. MIH codes are taken from the Forest Service Manual (1981), Chapter 1309.11. The MIH codes relevant to phase I are L02, L06, and L10: arterial, collector, and local road preconstruction, respectively. Preconstruction is defined as reconnaissance, route analysis, road location, survey, design, and field review. The reason for including all three types of forest roads is that arterial, collector, and local roads are artificial titles because of the high probability of error when coding for accounting purposes.

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[2]I had help in estimating the cost of the ID team members and organizational overhead from Marty Bouressa, Forest Budget and Finance Officer, Regional Office, Region 6, Missoula MT.

I collected the cost data from the PAMAR's accounting printouts for fiscal years (FY) 1980 to 1982 from MIH codes L02, L06, and L10. Under each MIH code there are specific appropriation numbers. The relevant appropriation numbers are _16, _83, _84, and _95 (the _ is used to signify the last digit of a given FY; e.g., for FY 81 the appropriation numbers are 116, 183, etc.). _16, _83 correspond to purchaser election and public works, while _84, _95 correspond to timber/purchaser.

The sum of the MIH categories, using the appropriate appropriation number, gives the total amount spent on preconstruction in any given FY; e.g., L02+L06+L10 = total amount spent.

The total number of miles that were completed in each MIH category for the given FY at the forest level were used to proportionally allocate the total dollars into a $/mi figure for each FY. An average of these three figures was used to net out any atypical years. Using the average $/mi figure and the total number of miles in the selected road, I estimated the dollars spent on preconstruction for a given road. This procedure was done for each of the four roads. The proportional arbitrary allocation of the preconstruction costs has no significant impact on the categorization procedure tested since these costs are joint across all outputs.

For phase II, construction, I collected road cost estimates and actual contract changes from the contract file or project file found in the engineering departments at the forest level. Inspection costs were determined from the PAMAR accounting data in a similar manner as was used in phase I. The MIH codes relevant to phase II are L03, L07, and L11 arterial, collector, and local road construction engineering, respectively. These MIH codes entail road construction staking and inspection (FSH, 1981). This gave a reasonable estimation of inspection and overhead costs for the four forest development roads chosen.

The final phase of the roading process is phase III, operation and maintenance. The maintenance costs are found in the appraisal sheet attached to the timber sale contract which is also kept in the project file. During the sale, approximately five years, the purchaser must maintain the road. The cost are prorated on an "MBF mile" basis. When a timber sale is drawn up, each cutting unit is defined and cruised to determine the total thousand board feet (MBF) in each cutting unit. A sale map with the transportation system superimposed on it defines the landings or log decking areas for each cutting unit. An MBF mile is the MBF from each landing divided by the mileage corresponding to that landing. The total MBF miles are multiplied by the dollar per MBF mile to determine a maintenance cost. Each

forest has an average dollar per MBF mile maintenance figure used when drawing up the timber sale.

After the sale is over, road maintenance becomes the responsibility of the engineering department. The MIH code L19 defines five different levels of road maintenance. For the purposes of this study road maintenance level three was used because it best described the road conditions of this study. Each forest level engineering department has an estimated maintenance cost per mile figure. The total miles of road are multiplied by the maintenance cost per mile to determine the total maintenance cost for a given road or sale.

The maintenance costs may be approximated by using the engineering department's estimates. To better approximate the maintenance costs I divided the time span involved into two categories: sale years and post-sale years. I made five major assumptions in determining the sale and post-sale maintenance costs:

1) The average timber sale lasts for five years with the purchaser conducting maintenance for the last three years of the timber sale;
2) The engineering department will maintain the road after the timber sale is completed (an annuity);
3) The long term real interest rate is 4% (Federal Register, 1982);

4) All dollar terms are in 1982 dollars;

5) The road maintenance level used is level three as defined by MIH code L19 (FSM, 1981).

To find the present value of the road maintenance costs for the sale years, I used a basic capital theory formula: The present value of a terminating annuity discounted two additional years.

$$P = \left(A * \frac{(1+i)^n - 1}{i(1+i)^n}\right) / (1+i)^t \qquad (6)$$

Where p = present value, A = the maintenance cost, i = real interest rate of 4%, n = 3 years, and t = 2 years. To find the present value of the road maintenance costs for the post-sale years, I used a perpetual annuity formula. Because the annuity does not start until after the sale is done, I discounted the annuity five years.

$$P = (A/i) / (1+i)^z \qquad (7)$$

Where P = present value, A = the maintenance cost, i = real interest rate of 4%, and z = 5 years. This was done for each of the four forest development roads.

AN EXAMPLE OF IDENTIFICATION AND CATEGORIZATION

There are three steps of identification and categorization, three phases of road development, and four example roads. The identification and categorization process was done at each phase of the road's development. This procedure was repeated for each of the four example roads. I will use an example from phase II, construction, of the road's development to illustrate the procedure of identification and categorization: a 24" culvert from one road. The initial contract called for 28 linear feet (L.F.) of 24" culvert at $15.00 per L.F. However, when building the road it was discovered that 8 more L.F. were needed because some culverts had to be relocated and some lengthened. The defined uses of the road were for timber (T), outdoor recreation (O), and mining (M). However mining only occurred from station 0+00 to station 17+00 and there were 10 L.F. of 24" culvert used in that piece of road. Alternative size 18" culvert costs $10.00 per L.F. All this information was collected from the road contract file, specifically the EAR and the schedule of items. Step 1 is simply a means of identifying the various items as they occur:

Step 1

ITEM SPECIFICATION	COST
603(01)b	$420
603(01)b	$120

The $420 is from the original contract; i.e., 28 L.F. * 15.00 $/L.F. = $420. The $120 is from the contract change. The notation 603(01)b denotes a 24" culvert, the numbers are taken from the Forest Service Standard Specification (1979) and are used in all road and bridge construction contracts.

Step 2 discerns between joint and non-joint costs. The four example roads I worked with had their primary purpose specified as timber; however, they all had other uses. During this step, I identified special problems areas that surfaced when working with each road. A common problem area that surfaced was identifying costs as joint and defining the products associated with the joint costs. A culvert provides an excellent example of the logical process used to identify joint costs and its corresponding products. A culvert normally produces only soils and watershed benefits. Culverts are sized to anticipate a 25 year flood. To just remove the timber, different combinations of in- and out-sloping, ditching, and waterbarring might have been used to control water run off and erosion. However, an 18" culvert is the minimum standard requirement of the Forest Service for controlling water runoff and erosion. In access decisions where harvesting lasts more than one season, the

discounted costs of the possible road repairs should be compared to the costs of installing the culverts.

My solution to the problem of identifying joint costs and corresponding products was simple. An 18" culvert will produce the joint products timber and soils and watershed. The culvert was chosen, because of the minimum standard requirements over the other methods of in- and out-sloping, ditching, and waterbarring causing the culvert cost to be the only investment expenditure, of this type, considered when building the road. If increasing the size of the culvert from 18" to 24" will not increase or decrease the amount of timber produced, the incremental cost of the larger culvert produces only the product or expected use of soils and watershed. The same logical process is taken with each such input problem that is encountered. This logic differs from the Host (1973) incremental approach: This study defines incremental costs on an investment by investment basis; e.g., the incremental cost of using a 24" culvert instead of an 18" culvert. This incremental cost is then identified and categorized as joint or non-joint depending on the implicit technical relationship between the products. Host's (1973) incremental approach assumes all costs above the "basic road" are incremental and proportionally allocates these incremental costs to the products that "require" the incremental cost (Appendix B - Critique). Host's use of the term "require" describes an

organizational or legal relationship, not necessarily a technical relationship between outputs, which is used to define joint products and costs. The approach I used to identify a technical relationship between outputs is based on the principle of derived demand for a factor input. Nicholson (1978) states the demand for a factor input is a derived demand based on the demand for the final output. For example, without the demand for soils mitigation there would be no demand for a culvert as a factor input. Now, a technical relationship must be established between the outputs soils (S) and timber (T). This implicit technical relationship came from the EAR and PER.

Resuming the 24" culvert example, step 2 defines joint and non-joint costs and products as follows:

Step 2

ITEM SPECIFICATION AND COST	CATEGORY
603(01)b $540	
603(01)b $120	S
603(01)b $100	T&O&M&S
603(01)b $50	S
603(01)b $180	T&O&S
603(01)b $90	S

603(01)b $540 is a heading to denote that I am working with a 24" culvert whose final cost amounted to $540. The products were determined from the logical process defined

above. 603(01)b $120 was categorized as S. The algebra is simple 15.00 $/L.F. * 8 L.F. = $120. The original design and contract is used as a basis for comparison. The product was determined from the change order. Relocating and lengthening culverts only affects soils and watershed by allowing water to move more freely through the culvert but has no effect on timber access. If the road could have been built without the culverts needing to be lengthened or relocated, the additional charge of $120 would not have been needed.

603(01)b $100 was categorized as T&O&M&S. The algebra was 10 $/L.F. * 10 L.F. = $100. The basic 18" culvert is required by roading policy for a basic multiple use road. I assumed there was technical relationship between these products. The culvert allowed recreational and mining traffic and logging trucks to move more freely over the road; e.g., not having to slow down to cross water bars. Only 10 L.F. were needed between station 0+00 and 17+00 where the mining activity was going on.

603(01)b $100 was categorized as S, 5 $/L.F. * 10 L.F. = $50. The basic culvert requirement is 18", any increase in size does not technically affect T&O&M. Therefore, the additional cost of the 24" culvert is for S. The 5 $/L.F. is the cost differential for using a 24" culvert; 15 $/L.F. - 10 $/L.F. = 5$/L.F. 603(01)b $180 was categorized as T&O&S, because only 10 L.F. were needed in the mining

section, 18 L.F. were used elsewhere on the road. The algebra and the logic is the same as that used to calculate 603(01)b $100. 603(01)b $90 was categorized as S. Again the logic is the same as that used to calculate 603(01)b $50.

Step 3 defines reasons for separating costs between joint and non-joint costs.

Step 3

ITEM SPECIFICATION AND COST	CATEGORY
603(01)b $540	
603(01)b $120	Smd
603(01)b $100	Tcmp&Ocmp&Mcmp&Scmp
603(01)b $50	Sm
603(01)b $180	Tcmp&Ocmp&Scmp
603(01)b $90	Sm

The joint products were determined in Step 2. Of interest here are the lower case letters denoting rationales for determining separable costs and joint products. 603(01)b $120 is a mitigation and discretion cost. It was the engineer's prerogative (discretion) to increase the length of some of the culverts to allow for mitigation of soils and watershed. 603(01)b $100 is the cost reflecting the policy constraint for installing a culvert. This becomes a production cost because of constraint; i.e.,

culverts are required when building a forest road. The culverts basic use is for mitigation of soils and watershed. 603(01)b $50 is the cost differential for using a 24" culvert instead of an 18" culvert. It is a mitigation cost, because increasing the culvert size has no technical effect on T&O&M. The increased culvert allows better water flow for the mitigation of soils and watershed. 603(01)b $180 is the cost reflecting the policy constraint for installing a culvert. The reasons for the notation "cmp" are the same as 603(01)b $100. The product or expected use mining is not included because that use does not occur past station 17+00. 603(01)b $90 is the cost differential for using a 24" culvert instead of an 18" culvert. The reason for the cost definition or expected use is the same as 603(01)b $50.

When working with investment costs such as excavation and embankment (203) which are linked to products or uses unique to given segments of road as with mining, I use simple proportionality to spread costs. For example, the total cost of 203 was $12,000 and there were 52+80 stations, the per station cost was $2.27. While this introduces arbitrary allocation, the costs could be more specifically disaggregated on a specific road by an engineer familiar with both the categorization procedures and the specific rather than average road building costs at each station.

THE TECHNIQUE EVALUATION

The technique evaluation is divided into two sections: 1) evaluating the technique's ability to minimize the amount of costs discerned to be joint, and 2) evaluating each step of the technique to determine if one should proceed to the next step. I will explain the evaluation methodology of section 1 first.

This section evaluates the technique's ability to minimize the amount of costs discerned to be joint. This was accomplished by determining the percent of the road's total cost were defined as joint versus non-joint. The percents were determined for each of the four roads by phase of road development and by product groupings. A summary sheet was compiled to show the maximum, minimum, average, and standard deviation values aggregated by phase.

The second section evaluates each of the three steps of the technique to determine if one should proceed to the next step. To perform this evaluation, all identification and categorization was first completed. Next, roads were aggregated first by phase of road development and then by each step of identification and categorization. For example, under phase II of road development, all the road's costs identified and categorized under step 1 of the categorization technique would be grouped together, and the roads' costs identified and categorized under step 2 would

be grouped together, etc. Finally, there were four criteria used to evaluate each of the three steps of categorization:

1) utility - the state or quality of being useful;
2) practicality - suitable for actual use;
3) complexity - composed of many, often connected, parts;
4) cost versus the value of information - a relative measure to indicate "cost - benefit" analysis.

The criteria were ordinally ranked from 1 to 3: 1 denotes the greatest benefit or lowest cost. For example, using phase II of road development and the first criterion, step 1's utility is ranked 3, step 2's utility is ranked 2, and step 3's utility is ranked 1. There should be no tied rankings. The mean of the rankings was used to compare between the steps of identification and categorization.

RESULTS

The results chapter is split into two main sections: 1) the results of categorization in limiting joint costs, and 2) the results from evaluating each step of the identification and categorization technique.

RESULTS OF CATEGORIZATION IN LIMITING JOINT COSTS

Tables 1 through 4 illustrate the percent of the total roads' costs defined as joint by phase of road development. Phase I, planning and design, identified the tradeoffs from the use conflicts. In phase II, construction, the tradeoffs between the use conflict were estimated. Therefore, the majority of the roads' costs appear in phase II, construction.

Tables 5 through 8 illustrate these tradeoffs in the percent of the total roads' costs defined as joint by phase and product groupings. Table 5 shows six products were served by the road: A, T, O, M, F and S. The constraint rationale for separability occurred in 71.14% of the road's total cost. Table 6 shows four products were served by the road: A, T, S, and F. The constraint rational occurred in 85.83% of the road's total cost. Table 7 shows five products were served by the road: A, O, S, T, and F. The constraint rational occurred in 51.11% of the road's total

TABLE 1
MATTIE V (COLLECTOR ROAD)
LOLO NATIONAL FOREST
Percent by Phase

PHASE	COST	PERCENT OF TOTAL
I. Planning and design		
Joint	2,500	1.57%
Non-Joint	00	00%
II. Construction		
Joint	132,487.34	83.33%
Non-Joint	6,460.07	4.06%
III. Operation and maintenance		
Joint	4,379.59	2.75%
Non-Joint	13,157.62	8.28%
IV. Aggregate total		
Joint	139,366.93	87.66%
Non-Joint	19,617.69	12.34%

TABLE 2
COUGAR CREEK (LOCAL ROAD)
CLEARWATER NATIONAL FOREST
Percent by Phase

PHASE	COST	PERCENT OF TOTAL
I. Planning and design		
Joint	12,985	8.44%
Non-Joint	00	00%
II. Construction		
Joint	38,844.20	25.26%
Non-Joint	87,364.80	56.81%
III. Operation and maintenance		
Joint	1,969.25	1.28%
Non-Joint	12,617.07	8.20%
IV. Aggregate total		
Joint	53,798.45	34.98%
Non-Joint	99,981.87	65.02%

TABLE 3
COUGAR RIDGE ROAD 9730 (COLLECTOR ROAD)
NEZPERCE NATIONAL FOREST
Percent by Phase

PHASE	COST	PERCENT OF TOTAL
I. Planning and design		
Joint	18,910	3.24%
Non-Joint	00	00%
II. Construction		
Joint	562,914.74	93.60%
Non-Joint	00	00%
III. Operation and Maintenance		
Joint	19,600.59	3.26%
Non-Joint	00	00%
IV. Aggregate Total		
Joint	601,425.33	100.00%
Non-Joint	00	00%

TABLE 4
HONEYBEE-BUMBLEBEE (LOCAL ROAD)
IDAHO PANHANDLE NATIONAL FOREST
Percent by Phase

PHASE	COST	PERCENT OF TOTAL
I. Planning and design		
Joint	22,930	14.02%
Non-Joint	00	00%
II. Construction		
Joint	95,174.16	58.18%
Non-Joint	6,969.76	4.26%
III. Operation and maintenance		
Joint	38,519.33	23.54%
Non-Joint	00	00%
IV. Aggregate Total		
Joint	156,623.16	95.74%
Non-Joint	6,969.76	4.26%

TABLE 5
MATTIE V (COLLECTOR ROAD)
LOLO NATIONAL FOREST
Percent by Product Groupings

PLANNING AND DESIGN	%	JOINT	%	NON-JOINT
Ao	1.57%	$2,500		
CONSTRUCTION	**%**	**JOINT**	**%**	**NON-JOINT**
TOMcp	25.97%	41,287		
TOcp	21.54%	34,241.55		
Sm			1.78%	$2,832.11
TOMScmp	1.73%	2,746.80		
TOScmp	3.31%	5,263.46		
Amd	18.43%	29,300.53		
FOm	0.54%	855		
Smd			2.28%	3,627.96
TOMScpd	0.77%	1,230		
TOMAcpd	6.79%	10,793		
TOMp	1.38%	2,200		
Ao	2.87%	4,570		
	83.33%	$132,487.34	4.06%	$6,460.07
TOTAL ROAD CONSTRUCTION COST PLUS INSPECTION			87.39%	$138,947.41
OPERATION AND MAINTENANCE	**%**	**JOINT**	**%**	**NON-JOINT**
TOMcmp	0.19%	$ 303.78		
TOcmp	1.03%	1,642.91		
MOcmp	1.53%	2,432.90		
Ocmp			8.28%	$13,157.62
	2.75%	$ 4,379.59	8.28%	$13,157.62
			11.03%	$17,537.21
TOTAL ROAD COST				$158,984.62

A = Administration
M = Mining or Minerals
F = Fish and Wildlife
O = Outdoor Recreation
R = Range and Forage
E = Environmental Amenities
S = Soils and Watershed
T = Timber

c = constraint
d = discretion
m = mitigation
o = overhead
p = production

TABLE 6
COUGAR CREEK (LOCAL ROAD)
CLEARWATER NATIONAL FOREST
Percent by Product Groupings

PLANNING AND DESIGN	%	JOINT	%	NON-JOINT
Ao	8.44%	$12,985		

CONSTRUCTION	%	JOINT	%	NON-JOINT
Tcp			52.38%	80,546.20
Scmd			3.19%	4,902.80
TScmp	12.76%	19,618.20		
Scmp			1.25%	1,915.80
FSAmd	0.67%	1,035		
TAcpo	6.77%	10,408		
Ao	5.06%	7,783		
	25.26%	$ 38,844.20	56.81%	$87,364.80
TOTAL ROAD CONSTRUCTION COST PLUS INSPECTION			82.07%	$126,209.00

OPERATION AND MAINTENANCE	%	JOINT	%	NON-JOINT
TScmp	1.28%	$ 1,969.25		
Scmp			8.20%	$12,617.07
	1.28%	$ 1,969.25	8.20%	$12,617.07
			9.49%	$14,586.32
TOTAL ROAD COST				$153,780.32

A = Administration
M = Mining or Minerals
F = Fish and Wildlife
O = Outdoor Recreation
R = Range and Forage
E = Environmental Amenities
S = Soils and Watershed
T = Timber

c = constraint
d = discretion
m = mitigation
o = overhead
p = production

TABLE 7
COUGAR RIDGE ROAD 9730 (COLLECTOR ROAD)
NEZPERCE NATIONAL FOREST
Percent by Product Groupings

PLANNING AND DESIGN	%	JOINT	%	NON-JOINT
Ao	3.14%	$18,910		

CONSTRUCTION	%	JOINT	%	NON-JOINT
TOSFcp	21.71%	$130,546		
TOcp	11.45%	68,850		
SFm	36.28%	218,200		
ATOSFcop	4.00%	24,081		
TOSFcmp	10.69%	64,292.02		
SFmd	2.08%	12,485.72		
SFOmd	0.17%	1,000		
Ao	7.23%	43,460		
TOTAL ROAD CONSTRUCTION COST PLUS INSPECTION			93.60%	$562,914.74

OPERATION AND MAINTENANCE	%	JOINT	%	NON-JOINT
TOSFcmp	0.36%	$ 2,175.74		
OSFcmp	2.90%	17,424.85		
	3.26%	$ 19,600.59		
TOTAL ROAD COST				$601,425.33

A = Administration
M = Mining or Minerals
F = Fish and Wildlife
O = Outdoor Recreation
R = Range and Forage
E = Environmental Amenities
S = Soils and Watershed
T = Timber

c = constraint
d = discretion
m = mitigation
o = overhead
p = production

TABLE 8
HONEYBEE-BUMBLEBEE (LOCAL ROAD)
IDAHO PANHANDLE NATIONAL FOREST
Percent by Product Groupings

PLANNING AND DESIGN	%	JOINT	%	NON-JOINT
Ao	14.02%	$22,930		

CONSTRUCTION	%	JOINT	%	NON-JOINT
TOSFcmp	12.46%	$20,389		
SFp	2.40%	3,927		
TOASFcop	1.20%	1,961		
TOcp	15.89%	26,003		
TOScp	11.69%	19,132		
Sm			4.26%	$6,969.76
ATOcop	2.91%	4,757		
TOScmp	0.39%	644.16		
TOFmp	0.47%	776		
Ao	11.83%	19,350		
	58.18%	$95,174.16	4.26%	$6,969.76
TOTAL ROAD CONSTRUCTION COST PLUS INSPECTION			66.44%	$102,143.92

OPERATION AND MAINTENANCE	%	JOINT	%	NON-JOINT
TOScmp	2.61%	$ 4,275.79		
OScmp	20.93%	34,243.54		
	23.54%	$ 38,519.33		
TOTAL ROAD COST				$163,593.25

A = Administration
M = Mining or Minerals
F = Fish and Wildlife
O = Outdoor Recreation
R = Range and Forage
E = Environmental Amenities
S = Soils and Watershed
T = Timber

c = constraint
d = discretion
m = mitigation
o = overhead
p = production

cost. Table 8 shows five products were served by the road: A, T, O, and F. The constraint rational occurred in 68.08% of the road's total cost. An average of 69% of the roads' total costs were in some way constrained by Forest Service policy.

Table 9 is an aggregate of the percent of costs categorized by phase. Roads 1 and 3 were collector roads and roads 2 and 4 were local roads. This table shows road type is important in the percent of costs categorized as non-joint products. As was expected, collector roads had a higher percent of the roads' total cost categorized as joint. This would be consistent with the definition of a collector road. Also, the variability in the percent categorized is associated directly with the decision process at each forest. If road uses are well defined in the EAR and PAR it becomes easier to divide multiple products into joint or non-joint products. For example, if the road was gated, explicit statements as to why the road was gated, the duration of closure, the uses of the road during closure, and the placement of the gate need to be answered to facilitate categorizing costs. Also, the fewer uses served by the road the easier it becomes to define multiple products as non-joint products.

Administrative actions are important in determining the percent of costs categorized as non-joint products versus joint products. The administration defines the production

Table 9

Aggregate Totals

ROAD ROAD TYPE		M C	CC L	CR C	H-B L
Phase I Planning and design	Joint Non-joint	1.57% 0.0%	8.44% 0.0%	3.14% 0.0%	14.02% 0.0%
Phase II Construction	Joint Non-joint	83.33% 4.06%	25.26% 56.81%	93.60% 0.00%	58.18% 4.26%
Phase III Operation and Maintenance	Joint Non-joint	2.75% 8.28%	1.28% 8.20%	3.26% 0.00%	23.54% 0.00%
Aggregate Total	Joint Non-joint	87.66% 12.34%	34.98% 65.02%	100.00% 0.00%	95.74% 4.26%

C = Forest Development Collector Road
L = Forest Development Local Road
% = Percent of Total Cost
M = Mattie V
CC = Cougar Creek
CR = Cougar Ridge
H-B = Honeybee-Bumblebee

function of the forest road. The production function defines whether the multiple products are technically dependent (joint) or technically independent (non-joint). This is consistent with Henderson and Quandt's (1980) definition of joint products. The administrative requirement of simultaneous production of two or more products does not necessarily constitute joint production. Using a road example, if a road was built to access a timber sale, if the road was gated at the entrance, if the road was closed during non-harvesting periods, and if the administration determined there were no other uses of the road, then products may easily be defined as non-joint. However, using the same simplistic example and changing the road closure policy allowing public access to firewood during certain periods of the year automatically defines the road's production as being joint with respect to timber and outdoor recreation.

In defining the production function, the administration also defines the number of outputs considered joint for each investment and the reasons for jointness. A road's production function consists of factor inputs; e.g., clearing and grubbing excavation, culverts, and etc. The reasons for jointness are defined by the lower case letters in categorization. The most prevalent reason for jointness was constraint (policy). The second reason was usually production. Most of the time constraint caused an

investment cost to be joint by limiting the minimum investment to be above that needed to serve the primary purpose of the road. The example I have often used is of a culvert.

Table 10, a statistical summary of table 9, shows the maximum, minimum, and mean percent of total costs categorized for each phase. The aggregate total line is a summary of percent of total costs categorized. Approximately 20% of these forest road's total costs were directly allocated by cost categorization. Categorizing a cost as a non-joint production cost is essentially allocating that cost to the non-joint product. Table 10 also shows that a majority of the costs categorized as non-joint products appear in phase II, construction, which usually contains the bulk of the costs and the majority of the use conflict problems.

THE RESULTS OF STEP EVALUATION

Table 11 gives the results for determining whether one should complete all three steps of the identification and categorization technique. The smaller the step's mean value the higher were the step's rankings. This is because the ordinal ranking was from 1 to 3: 1 denoting the greatest benefit or lowest cost. The rankings were the same across step and phase because there was no distinct difference

Table 10

Summary Statistics

		MAX	MIN	MEAN	S.D.
Phase I Planning and design	Joint	14.02%	1.57%	6.79%	5.64
	Non-joint	0.00%	0.00%	0.00%	0.00
Phase II Construction	Joint	93.60%	25.26%	65.09%	30.44
	Non-joint	58.61%	0.00%	16.28%	27.09
Phase III Operation and maintenance	Joint	23.54%	1.28%	7.71%	10.59
	Non-joint	8.28%	0.00%	4.12%	4.76
Aggregate	Joint	100.0%	34.98%	79.59%	30.18
	Non-joint	65.02%	0.00%	20.41%	30.18

MAX = Maximum Value
MIN = Minimum Value
S.D.= Standard Deviation

TABLE 11
TECHNIQUE EVALUATION

STEP	ORDINAL RANKING	MEAN
1. Identification		2.5
utility	3	
practicality	3	
complexity	1	
cost-benefit	3	
2. Categorization		2.0
utility	2	
practicality	2	
complexity	2	
cost-benefit	2	
3. Separation		1.5
utility	1	
practicality	1	
complexity	3	
cost-benefit	1	

between how a step worked given a phase of road development. This results in step 3 having the lowest mean or that all three steps of the identification and categorization technique should be used when identifying and categorization costs. Criterion rankings were determined simultaneously.

I will explain how each criterion ranking was determined beginning with utility. Utility was defined as the state or quality of being useful. Step 1's utility criterion was given a ranking of 3 because no actual cost categorization was done during this step. However, in this step the costs were identified, the documentation on the road was compiled, the contract changes were identified by the work orders or change orders, and the information was brought together in a workable form. This step was necessary before proceeding to the next two steps. Step 3's utility criterion was given a ranking of 1 because I felt it was the most useful. Not only did this step identify joint or non-joint products, but also defined reasons for jointness and cost separation.

Practicality was defined as suitable for actual use. Again step 1's practicality criterion was given the ranking of 3; however, of greater interest are the rankings of steps 2 and 3. Step 3's practicality criterion again received the highest rank because defining reasons for jointness and cost separation must be implicitly understood before products were identified as joint or non-joint.

Complexity was defined as composed of many, often connected, parts. Step 1's complexity criterion received the highest ranking here because it was simply paper shuffling. Step 3's complexity criterion received the lowest rank; because, explicitly defining reasons for jointness and cost separation requires more careful thought and understanding than to just implicitly know the reasons as required by step 2.

Cost versus the value of information was defined as a relative measure used to indicate a "cost-benefit" analysis. Step 1 again received the lowest ranking because no real useful information was determined, outside of the initial preparation required for steps 2 and 3. Step 3's cost benefit criterion received the highest ranking because I felt explicitly stating the reasons for jointness and cost separation were important: Insights were identified that could be used to change the road's production function so fewer products would be defined as joint. For example, identifying areas where constraint (policy) greatly affects the road's production function.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions are split into three sections: 1) the success of categorization in limiting joint costs, 2) the conclusions from evaluating the three steps of identification and categorization, and 3) some implications drawn from using the technique.

THE SUCCESS OF CATEGORIZATION IN LIMITING JOINT COSTS

There was limited success in using cost categorization to reduce the amount of costs identified as joint. Approximately 80% of the roads' costs were still defined as joint costs. Jointness was not random: A major reason for the majority of joint costs was the Forest Service's multiple-use mandate. The Forest Service may not initiate a project without examining the impact on all uses. These actions automatically create joint costs. Therefore, phase I's planning and design costs are automatically joint. The multiple-use mandate is reflected in road design policies; therefore, a basic use road concept is hard to define because most Forest Service actions result in predominantly joint production. Host (1973) used the basic road concept to develop an incremental approach to allocate joint costs (Appendix B - Critique). Host states:

> The 'basic road' concept consists of a hypothetical designed minimum standard road which is then used as a basis for comparison for the other requirements. Design standards are determined for

> each user class. Each class then contributes only to the cost of the highest level of standard which it actually requires and in proportion to that use.

Whether the use requires it or not is not the discerning factor between joint and non-joint production. However, the basic Forest Service forest development road is not the minimum standard a timber road could be built to. Even with Host's simplistic view of joint production and using his allocation technique, no one seems to ask the question of whether the minimum standard timber road requires an 18" culvert or any culvert at all. Yet, this investment is assumed to be part of the "basic road" concept for the Forest Service. Because of the multiple-use mandate a majority of road costs are considered joint when they might be identified and categorized as non-joint production costs by another timber organization's basic standards.

The success of cost categorization is not limited to the amount of costs identified as non-joint or joint costs. Cost categorization identified causes of jointness; i.e., the decision process which defines the production function. How the administration defines the production function is important. Table 9 showed that the forest road type did explain some variability in the percentage of costs categorized as joint or non-joint. The example roads were taken from both collector and local roads. Examining the road design standards or geometric criteria, the main differences I found were collector roads usually had more

turnouts per mile and a sustained maximum allowable grade less than a local road. This translates into slightly higher construction cost for collector roads. By definition a collector road receives more traffic and serves more uses than a local road. The uses of the roads and road management plans were similar: mainly timber and outdoor recreation uses and the roads were gated during hunting season. However, variability in the percent of the total costs categorized as joint is also associated with the decision process (administration) which defines the production function. The Forest Service, by law, may not optimize a single or a small specified group of products or uses and must consider the impact to all uses when making an investment. This mandate is the reason for the numerous joint products. The Forest Service provides an arbitrary market for these products. Providing a market and actually marketing the products are two different problems. There is an opportunity cost of outputs not marketed.

There is no need to use an arbitrary cost allocation technique on the portion of those costs that are not joint costs. Cost categorization directly allocates production costs associated with non-joint products and specifically identifies joint products and joint costs. Arbitrary cost allocation could then be performed on the identified lumps of joint costs and their corresponding products. Therefore,

cost categorization should be the first step in the cost allocation process.

CONCLUSIONS FROM STEP EVALUATION

Step 1, identification, was established as an introductory step, which gathered all the pertinent information dealing with the road and assembled the data in a workable form. I believe that step 1 is an important component of categorization, rather than a means of identifying and categorizing costs.

In steps 2 and 3 the actual categorization and separation was performed, respectively. Table 11 shows there was no variation in the rankings due to phases or roads. There was no distinct difference between how a step of the identification and categorization technique worked given a phase of road development

Table 11 gives the results of step evaluation. Using each step's overall mean, I would conclude that all three steps of the identification and categorization technique should be used. The only difference between steps 2 and 3 is defining the separability of costs. This difference was examined when I explained the rankings of each evaluation criterion. To briefly reiterate: the implicit knowledge used in step 2 to decide cost separability and whether joint products exist becomes explicit in step 3. Without the

explicit statement, no one would know the reasons for jointness and cost separability. I feel this explicit information is useful in possibly reducing overall road costs and/or reducing the number of costs identified as joint.

CONCLUSIONS DRAWN FROM USING THE TECHNIQUE

Table 9 showed that approximately 20% of the forest roads' total costs were directly allocated by cost categorization. When a large number of resources are served by the road; e.g., five or more resources, too many use conflicts develop and fewer costs are discerned to be non-joint. Tables 5, 7 and 8 show this: approximately 87%, 100% and 95% of the roads' total costs were discerned to be joint, respectively. This was due to road type and how the EAR and PER, which defines the roads' production function, were written. Tables 5 and 7 depicted collector roads and Table 8 depicted a local road. When four or less resources are served by the road, there is a higher probability of having fewer use conflicts develop and cost categorization might directly allocate more of the forest road's total cost. Table 6 shows that approximately 65% of the local road's total costs were discerned to be non-joint.

Production and distributional efficiency rationales may be facilitated by the recommended categorization technique.

Production decisions for outputs imperfectly priced or not priced must rely on policy guidelines or cost effective comparisons between production alternatives and the physical output of each alternative; because, without output price marginal benefit may not be equated to marginal cost. Policy guidelines accounted for an average of 69% of a road's total cost. This technique could be used by decision makers who are denied knowledge of product price and must rely on subjective cost measurement comparisons between the production alternatives and the physical output of each alternative. The recommended technique would lend itself to incremental analysis of alternative investment plans; e.g., a waterbar versus a culvert. This incremental or marginal analysis would help in making efficient production decisions. Finally, the recommended technique partially defines a cost that may be used as price proxy for marginal cost based distributional decisions.

The recommended technique could lend itself to a policy or organizational analysis. One may identify areas of study that might reduce overall costs or reduce those cost identified as joint. Step 3, separation, not only categorizes costs but defines their separability. For example, an 18" culvert is the minimum policy requirement and was categorized as TScmp. The joint products are timber (T) and soil and watershed (S). The lower case letters define the investment cost as nonseparable: constraint (c),

mitigation (m), and production (p), and define the reason the cost was incurred. The cost is a production cost because of constraint (policy), and a mitigation cost because the basic use of a culvert is mitigation. To reduce the cost of installing the culvert, production aspects could be examined. To reduce the jointness, constraint aspects might be examined. This shows the direct value of the additional information given by step 3, separation.

The recommended technique might be too fine a tool for accounting and auditing purposes because of the size of the U.S.F.S. and the number of miles of road built by the U.S.F.S. However, if consistency could be developed and maintained in recording and aggregating costs, a researcher could back track through the present system without too much difficulty.

P.L. 88-657 provides the legal basis for cost allocation and therefore cost categorization. The public law briefly states the purchaser of national forest timber should only pay road costs directly associated with removing the timber. Because of the multiple use mandate and high basic standards, categorization could only identify a small proportion of directly allocatable non-joint costs. If allocation is necessary beyond this point an arbitrary method would have to be used to assign a cost to a specific use.

To summarize, there are three uses of cost identification and categorization: 1) distinguishing joint from non-joint cost for future cost allocation, 2) facilitating efficient production decisions, and 3) budgeting uses. Cost categorization is useful but should not be totally relied on to allocate production costs. Cost categorization will reduce the total amount subject to, but not negate, the need for arbitrary joint cost allocation. In addition, cost categorization identifies specific uses or products associated with the joint or non-joint cost plus defining reasons for jointness and cost separation. Therefore, cost categorization should be used as a first step in the cost allocation process. The incremental cost data provided by cost identification and categorization will facilitate efficient production decisions. Finally, the joint production of two or more technically related outputs is cheaper than if the outputs are produced singly. Cost identification and categorization will provide this cost information. This has budgetary implications.

CONCLUSIONS DRAWN FROM THE RESEARCH

Present Research

There are some problems with the techniques developed in the present study. When categorizing costs one must be

careful to identify all concerns, for if one aspect is overlooked a completely different interpretation of the cost category will be made. Often this will require cost detail available to an engineer trained analyst. In the culvert example, if the cost was categorized as STmp instead of STcmp, a completely different interpretation would be made. This type of error would create a point of controversy if a policy analysis was being done. Other techniques of categorizing costs might be identified and compared to this technique. I lacked the engineering expertise to do any fine incremental analysis; consequently, the incremental analysis I did had to be proportional. With the help of an engineer, a single road might be more rigorously examined and the incremental analysis more finely done. However, it is unlikely that the ratio of joint to non-joint production costs would significantly change.

Concurrent Research

Dr. John Hof, Rocky Mountain Station U.S.F.S. refines the comparative statistics of joint costs using cost minimization and the problems involved in allocating joint costs. He proves mathematically what I implicitly showed that only part of the total cost is nonallocatable. Dr. Hof uses linear programming to show that "when the two outputs are (minimum) costed individually, the total cost overestimates the joint cost of both outputs" when the

outputs are complementary. Therefore, if costs were allocated as a result of the individual output costs, the errors being made result in misallocation of forest resources. Dr. Hof's explicit method of identifying joint costs becomes overly complex with more than two outputs, while my implicit system may handle a more complex production process. A combination of the two studies is possible and would be fertile grounds for future research.

RECOMMENDATIONS

The problem remains of allocating those costs identified and categorized as joint costs. The primary rationale for this research is P.L. 88-657, which defines the legal basis for cost allocation. This research would entail an in depth comparison of the arbitrary allocation techniques that are presently available. If none of these allocation techniques proved adequate, a new system could be developed. Ungar (1980) is an excellent starting point for a brief overview of the joint cost allocation techniques currently available.

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GLOSSARY

Administrative Costs - - These costs cannot be described by a single product or small grouping of the products of the acronym AMFOREST. These costs entail some aspect of all the products. The Forest Service Manual (1982) states administration costs are "a cost of line officers, their immediate clerical staff, and common services (such as joint-use facility and equipment management). It is a fixed cost."

Constraint cost(s) - - Cost(s) mandated by Forest Service Regulations for building roads; e.g., cost incurred to install a basic culvert for a stream.

Discretion cost(s) - - Cost(s) that are unnecessary but deemed necessary by the manager; e.g., extra cost incurred to save an endangered habitat or animal species, or the addition of an extra turnout.

Independent products (costs) - - Cases in which a single firm produces two or more technically independent products (Henderson and Quandt, 1980). (See non-joint products)

Joint products (costs) - - The case of joint products is distinguished on technical rather than organizational grounds and exists whenever the quantities of two or more outputs are technically interdependent (Henderson and Quandt, 1980). The Federal Register's (1982) joint costs definition is "a cost contributing to the production of more than one type of benefit." Inherent in this definition is multiple production is not the result of budgetary aggregations.

Mitigation costs - - Are costs associated with reducing negative effects caused by a road's construction and use; e.g., the seeding of road cutbanks to reduce non-joint sources of sedimentation. Hyde and LeMaster (1979) use the concept of externalities to define what mitigation costs are.

> External costs are the costs of some activity, timber production in this case, borne by second parties without compensation. For example, they would accrue in the postulated situation if eroding soil from poorly constructed roads damaged a fishery or if critical wildlife habitat were destroyed in the process of growing or harvesting timber. Amounts of such costs are reflected in the costs of mitigation, as in road improvements to reduce erosion and the resulting sedimentation.

Multiple products - - A production process resulting in two or more products.

Non-joint products (costs) - - Cases in which a single firm produces two or more technically independent products (Henderson and Quandt, 1980). (See Independent products)

Non-separable cost(s) - - Input cost(s) that may not be clearly delineated into specific products, activities, or outputs. There are two types (see below).

Non-separable joint cost(s) - - Input cost(s) that are not directly attributable to technically dependent products, activities, or outputs; e.g., the same system road bed provides equal access to timber harvesting protection, and dispersed motorized recreational use functional outputs.

Non-separable non-joint cost(s) - - Input cost(s) that are not directly attributable to technically independent products, activities, or outputs; e.g., the same system road bed providing equal access to fishing and hunting activities.

Overhead cost(s) - - "They refer to costs that cannot be traced home and attributed to particular units of business in the same direct and obvious way in which, for example, leather can be traced to the shoes that are made from it." (Clark, 1923).

Production cost(s) - - Cost(s) directly associated with the output; e.g., the cost to run a dozer to build the road.

Separable cost(s) - - Input cost(s) that may be directly and uniquely delineated into specific product(s), activity(ies), or output(s); e.g., the extra construction costs of a turnout for a scenic over look is directly associated with aesthetic use of the highway. The Federal Register (1982) defines a separable costs as "an identifiable portion of costs of jointly used, manmade resources or services that are required by or contribute to only one objective or output". This only holds true if only one output is produced.

APPENDIX A

THEORY

DEFINITIONS OF NON-JOINT AND JOINT PRODUCTION

A multiple production process is one that has two or more outputs. These can either be non-joint products (technically independent) or joint products (technically dependent). In the simplest case, the production function is the technical relationship between two products (y1,y2) and the resource input (x). Relationship between the resource input (x) and the two products (y1,y2) may also be developed, $x=g(y1,y2)$, and is used to mathematically define production as either non-joint or joint (Carlson 1974, Henderson and Quandt 1980, and Shumway et. al. 1983).

The partial derivative of x with respect to y1 or y2, $\partial x/\partial y1$ or $\partial x/\partial y2$, are referred to as marginal coefficients of production or the marginal factor requirements (Carlson, 1974, and Shumway et al., 1982) and express the rate of change of the resource input with respect to a change in the output of a product. It is assumed the marginal coefficients of production vary with the quantities of the products produced in such a way that when y1 increases while y2 is held constant, or when y2 increases while y1 is held

constant, the marginal coefficients of production $\partial x/\partial y1$ and $\partial x/\partial y2$ also increase, at least after a certain minimum quantity of output has been produced. That is, beyond a minimum output the second partial derivatives $\partial^2 x/\partial y1^2$ and $\partial^2 x/\partial y2^2$ become positive. In addition, the marginal coefficients of production of one product may also vary, either increase or decrease, with a change in the output of the other product: It is this variation which represents the peculiar characteristics of joint production (Carlson, 1974). If the cross-partial derivatives of x with respect to y1 and y2 are less than or greater than zero, production is joint (Carlson, 1974).

The marginal coefficients of production are used to mathematically define non-joint and joint products instead of marginal productives. Using a simple example, the production functions are given by $y1=f(x,y2)$ and $y2=f(x,y1)$.[1] The production functions are defined using the same functional operater. This defines a special symmetric

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[1]Production occurs when $\partial y1/\partial x>0$ and $\partial^2 y1/\partial x^2<0$, or $\partial y2/\partial x>0$ and $\partial^2 y2/\partial x^2<0$.

function; e.g., $y1=x-y2$ and $y2=x-y1$. The marginal productivity of x with respect to y1, $\partial y1/\partial x$, is defined at a constant value of y2. The derivative $\partial(\partial y1/\partial x)/\partial y2$ would be used to express how this marginal productivity, $\partial y1/\partial x$, changes with a change in y2. However, this derivative, $\partial(\partial y1/\partial x)/\partial y2$, does not exist. By defining the production functions as I have done, the only way to increase y2, when y1 is held constant, is to increase x. But when x changes so does y1; therefore, y1 is not held constant when taking the cross-partial derivative (Carlson, 1974). In addition, changing x will necessarily change the marginal productivity of x with respect to y1. Therefore, the marginal productives, in this simple case, may not be used to mathematically define joint or non-joint products.

The mathematical definitions examine both the primal (main, or of first importance) and dual definitions. Duality is important because cost functions are econometrically easier to estimate than production functions. A cost function is the relationship between the more observable factor prices and physical output levels. If the cost function is mathematically well-defined; i.e.,

the function is twice differentiable and quasi-concave (Silberberg, 1978), there is a real and unique underlying production function. If the cost function subject to an output constraint is defined as joint, then by duality the production function will also be joint (Shumway et al., 1982, Henderson and Quandt, 1980, Silberberg, 1978, and Carlson, 1974).

Non-joint Products

Non-joint products are technically unrelated. The primal definition of non-joint products requires a relationship exists between the resource input x and either y1 or y2 but not both. Carlson (1974) and Shumway et al. (1982) represent this as

$$\partial(\partial x/\partial y1)/\partial y2=0. \qquad (1)$$

The cross-partial derivative of x with respect to y1 and y2 equals zero. This means a change in the production of y2 will not affect the marginal coefficient of production for y1. The primal and dual relationships hold for non-joint products.

Joint products

Joint products are technically dependent. The definition by Henderson and Quandt (1980) is the study's primary definition:

> The case of joint products is distinguished on technical rather than organizational grounds and exists whenever the quantities of two or more outputs are technically interdependent. Cases in which a single firm produces two or more technically independent products are excluded from this definition.

This definition is important for two reasons: 1) it clearly distinguishes joint products as a subset of multiple products, by contrasting them on technical rather than organizational grounds; and 2) it defines the cause of jointness, technically independent versus technically dependent.

Joint products are further divided into two categories based on product proportions. Gregory (1972) explains that

> two types of joint production may be distinguished. In one the products are produced in 'technically fixed proportions' (wheat and straw, beef and hides, mutton and wool, etc.) and in the other the products' proportions are 'technically variable'.

Joint production with fixed product proportions is more easily recognized than joint production with variable product proportions. This does not reduce the problems associated with joint cost allocation or the need for cost identification and categorization.

Shumway et al. (1982) and Carlson (1974) give similar mathematical interpretations of Henderson and Quandt's (1980) joint products definition with technically variable proportions

$$\partial(\partial x/\partial y1)/\partial y2 \neq 0. \qquad (2)$$

The cross-partial derivative of x with respect to y1 and y2 does not equal zero. This means a relationship exists between the resource input and the two products. Furthermore, this relationship may be greater than zero or less than zero. To understand the above relationships it is easier to examine the greater than zero and less than zero conditions separately.

Carlson (1974) uses

$$\partial(\partial x/\partial y1)/\partial y2 < 0 \qquad (3)$$

to define joint products that are technically complementary. This means increasing the production of y2 causes the marginal coefficient of production for y1 to decrease (Carlson, 1974). The marginal coefficient of production of Y1, $\partial x/\partial y1$, is the rate of change of x with respect to the rate of change of y1, this ratio must decrease by definition. If the production of y2 is increased there must be an increase in x. In order for the marginal coefficient of production for y1 to decrease, with an increase in x, y1 must increase faster than X. Therefore an increase in the production of y2 causes an increase in the production of y1.

Carlson (1974) uses

$$\partial(\partial x/\partial y1)/\partial y2 > 0 \qquad (4)$$

to define joint products that are technically competing. This means increasing the production of y2 causes the marginal coefficient of production of y1 to increase (Carlson, 1974). If the production of y2 is increased there must be an increase in x. In order for the marginal coefficient of production of y1 to increase, with an increase in x, y1 must decrease faster than x. Therefore an increase in the production of y2 will cause a decrease in the production of y1.

The primal and dual relationships also hold for complementary and competing joint products.

DETERMINING SUPPLY CURVES UNDER JOINT PRODUCTION

Joint cost allocation is not necessary for determining the supply functions or supply curves using either the profit maximization model or the cost minimization subject

to an output constraint problem.[2] This section relied solely on Henderson and Quandt's 1980 microeconomic text: Microeconomic Theory, A Methematical Approach.

The Production Function

The production process is defined by the transformation function, equation 5, which defines the efficiency locus.

$$G(y1, y2, x) = 0 \tag{5}$$

Assume equation 5 may be solved for x:

$$x = g(y1, y2). \tag{6}$$

Equation 6 is the cost of production in terms of x (Henderson and Quandt, 1980) and defines a production possibility frontier, when x is held constant and y1 and y2 are allowed to vary. Equation 6 is assumed to be a positive-valued increasing function over a domain in which y1 and y2 are positive or nonnegative (Henderson and Quandt, 1980). Also equation 6 is assumed to be strictly concave for profit maximization and quasi-concave for constrained optimization (Henderson and Quandt, 1980). The slope of

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[2]The production of joint products does not require an extended analysis unless they can be produced in varying proportions. If two products are always produced in fixed proportions, where $y1/y2=k$ where k is a constant, the analysis for a single output can be applied. Define a compound unit of output as k units of y1 and 1 unit of y2 with a price of $kp1 + p2$ and treat it as a single output (Henderson and Quandt, 1980).

the tangent to a point on a production possibility frountier defines the rate at which y2 must be sacrificed to obtain more y1, ceteris paribus. The assumption that equation 6 is a positive-valued increasing function "ensures that both marginal products are positive, as rational operation requires; the slopes of the product transformation curves (production possibility frontier) are negative; and the RPT (rate of product transformation) is positive. . . . Such product transformation curves are bowed away from the origin" (Henderson and Quandt, 1980).

The supply functions may be derived from the profit maximization model (Henderson and Quandt, 1980 and Silberberg, 1978). I will assume the firm is a price-taker in both factor input and output markets. Equation 6 is strictly concave and twice differentiable so that the second-order conditions for a maximum are satisfied (Silberberg, 1978).

The model is formulated by

$$\max_{\{y1,y2,x\}} \pi = p1y1 + p2y2 - wx \qquad (7)$$

subject to

$$G(y1,y2,x) = 0$$

This may be rewritten as

$$\underset{\{y1,y2\}}{\mathrm{MAX}\pi} = p1y1 + p2y2 - w[g(y1,y2] \tag{8}$$

To maximize, set the first derivatives equal to zero

$$\frac{\partial\pi}{\partial y1} = p1 - w\frac{\partial g}{\partial y1}(y1,y2) = 0 \tag{9.1}$$

$$\frac{\partial\pi}{\partial y2} = p2 - w\frac{\partial g}{\partial y2}(y1,y2) = 0 \tag{9.2}$$

9.1 and 9.2 may be rewritten as

$$w = p1\frac{\partial y1}{\partial g(y1,y2)} = p2\frac{\partial y2}{\partial g(y1,y2)} \tag{10}$$

The firm would "increase profits by increasing its employment of x if its return in the production of either product exceeds its cost" (Henderson and Quandt, 1980). Equation 10 simply states that the wage, the marginal factor cost, must equal the value of the marginal product of y1 and y2.[3] Cost allocation is not necessary to decide how much y1 and y2 to produce.

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[3]For the case of fixed output proportions, the efficiency condition would be when marginal factor cost equals marginal revenue product, where marginal factor cost is the cost of employing an additional unit of the factor input, and where marginal revenue product includes the additions to total revenue from both outputs.

The supply functions for firm are obtained from the first-order conditions for profit maximization by letting price equal marginal cost (Henderson and Quandt, 1980). Equations 9.1 and 9.2 may be rewritten as

$$p1 = w\frac{\partial q}{\partial y1}(y1,y2) \quad (11.1)$$

$$p2 = w\frac{\partial q(y1,y2)}{\partial y2} \quad (11.2)$$

Given the assumption the firm is a price-taker in the input and output markets, the left-hand side of equations 11.1 and 11.2 denotes marginal revenue and the right-hand side of equations 11.1 and 11.2 denotes marginal cost. Marginal revenue equals price under the assumption the firm is a price-taker in the output markets. Marginal cost is defined as the wage rate of the input divided by the marginal product of x. The firms marginal cost curve may be drawn by holding the wage rate constant and allowing the marginal product of x to vary. The firm's short-run supply curve is the positively sloped portion of the marginal cost curve above the short-run average variable cost curve. For output prices below the minimum point on the short-run average variable cost curve, the quantity supplied would be zero (Henderson and Quandt, 1980).

The assumptions about equation 6 and the second-order conditions for a maximum requires that

$$-w\partial^2 g(y1,y2) \;/\; \partial y1^2 < 0 \qquad (12.1)$$

and

$$-w\partial^2 g(y1,y2) \;/\; \partial y2^2 < 0 \qquad (12.2)$$

Since $w>0$, $\partial^2 g(y1,y2)/\partial y1^2$ and $\partial^2 g(y1,y2)/\partial y2^2$ must be positive. These second partial derivatives, $\partial^2 x/\partial y1^2$ and $\partial^2 x/\partial y2^2$, being positive exactly correspond to the assumption Carlson (1974) used to define joint products as technically competing or complementary. Therefore, the marginal cost of each output in terms of x is positively sloped (Henderson and Quandt, 1980).

Therefore, cost allocation was not necessary to determine the supply curves for the firm.

Cost Minimization

The cost minimization problem is a necessary condition for profit maximization, but not a sufficient condition (Silberberg, 1978). The cost minimization problem minimizes cost subject to a given output level. The profit maximization model finds the optimal level of output given

output and input prices; i.e., the level of output is a decision variable. The output level used in cost minimization might not be the optimal output level given by the profit maximization model. However, in order to maximize profits, costs must be minimized. Therefore, if costs do not need to be allocated to determine the supply curve when maximizing profits, cost allocation is also not necessary to determine the supply curves using cost minimization.

APPENDIX B

CRITIQUE

This critique examines two of the most relevant cost allocation techniques dealing with the problems of forest roads: 1) Host's 1973 Master's Thesis from the University of Montana, and 2) Separable cost/remaining benefit technique preferred by the Forest Service. I will critique Host's thesis first.

ALLOCATING ROAD COSTS UNDER U.S.F.S. POLICY CONSTRAINTS

Host (1973) developed an incremental technique of joint cost allocation to help the U.S.F.S. in allocating road costs among all user groups. It is based on the "basic road" concept. Host, 1973, states:

> The 'basic road' concept consists of a hypothetically designed minimum standard road which is then used as a basis for comparison for the other requirements. Design standards are determined for each user class. Each class then contributes only to the cost of the highest level of standard which it actually requires and in proportion to that use.

Two problems are readily apparent by using this incremental method. One is the "basic road" concept. U.S.F.S. road building policy for a minimum standard road is already a multiple use road. The environmental analysis report (EAR) for the Mattie V sale on the Lolo National Forest stated:

"It is not feasible to reduce road costs by reducing standards as they are already considered to be minimum for land management objectives of use and protection." The second problem is that by increasing the standard of the road, one increases the number of joint products: e.g., standard level II produces products of both level I and II, not just level II.

There are two versions of Host's model: 1) equal shares method, and 2) proportional shares method. In his equal shares approach, Host uses a timber harvest road as the basic minimum standard road. Again, current U.S.F.S. road policies make the concept of the basic road impractical. Because the basic road is the bottom step in producing higher standard roads, its costs are common to all considered uses. The allocation model states that the sum of these basic road costs should be divided by the number of uses the road will serve. Host's equal shares method states increases in road standards; e.g., using roadbed width as the criteria, will be charged to those uses that require the increase in road standards. These incremental road costs should be divided by the number of users that require the increase in road standards. Each additional increment will be handled in a similar manner. Ungar (1980) defines this as the equal shares method of allocating joint costs, and identifies problems with using this method for allocating joint costs.

There are two problems with this proposed method of allocation. The first is using the equal shares method of allocating joint costs. From an accounting standpoint there is nothing wrong with this method, each use is charged some amount. Since there were no economic considerations used to define how costs were allocated, no economic interpretations may be given (Ungar, 1980). The second problem is the simplistic view of joint production. Host (1973) assumes that each use "contributes only to the cost of the highest level of standard which it actually requires." Joint products are defined by a technical relationship, not an organizational or legal relationship. Whether a product "requires it" is not the discerning factor to separate joint products (costs) from non-joint products (costs). Using roadbed width as the primary criterion for distinguishing incremental increases in road standards, Host's supposition is that the incremental cost of increasing the roadbed width from 14 to 16-feet should not be charged to timber, wildlife, or forage because these uses do not require a 16-foot roadbed. Instead those incremental costs should be charged to watershed, recreation, and administration. However, by increasing the roadbed width, the decision maker is also allowing timber to flow more freely with respect to those other uses. Therefore, this incremental cost is technically complementary with respect to timber production

and water, recreation and administration production and timber should be included in the list of incremental uses.

The second method, proportional shares, uses the same assumption as the equal share method. Simply, one determines the percent effect each use has on an action: e.g., excavation. This percent effect, "the index of cost allocation", is then multiplied times the total cost of the action to determine each use's allocatable effect. Again, the same two problems exist with this method.

In conclusion, Host, 1973, agrees "there is no perfect way to allocate road costs among all user groups." He also states: "Some arbitrariness is needed in order to present this method" confirming the theoretical inconsistency of joint cost allocation.

SEPARABLE COST/REMAINING BENEFIT

Separable cost/remaining benefit cost allocation system was recommended by the Water Resource Council in 1980 (Federal Register, 1980). In 1982, the Federal Register and the Forest Service Manual (1982) stated separable cost/remaining benefit is "the preferred method" of allocating costs. This means the Forest Service is not required to use separable cost/remaining benefit as a method to allocate costs. P.L. 88-657 requires costs allocation. With no set technique to allocate costs, inconsistencies in

allocating costs will develop in forests intra-regional and inconsistencies in allocating costs will develop inter-regional. It is interesting to note that both the Federal Register, 1982, and the FSM, Chapter 1970, state: "All existing cost allocation methods are arbitrary."

Critical Review

The terminology used to describe separable cost/remaining benefit is vague. The description is divided into four sections: 1) General, 2) Definitions, 3) Cost Allocation Standard, and 4) Allocation of Constituent Cost. I will examine each part individually, starting with the first section.

Section one, General, gives the rationale for cost allocation and specifies who costs are to be allocated to. The Federal Register (1980) states:

> Cost allocation among purposes (a product or use) and the apportionment of cost shares to Federal and non-Federal public and private interests are necessary for preparation of RED (regional economic development) and OSE (other social effects) accounts.

RED is defined as an account that "registers changes in the distribution of regional economic activity that result from each alternative plan" (Federal Register, 1980). The two measures of economic activity are regional income and regional employment. RED accounts are used to compare alternative plans. An example of using the RED account might be to use regional employment and income multipliers

to estimate changes resulting from an increase or decrease in the amount of timber cut. OSE accounts "include the following urban and community impacts: life, health, and safety factors, displacement, long-term productivity, and energy requirements and energy conservation" (Federal Register, 1980). OSE accounts seem to try and capture externality effects. OSE accounts are also used to compare alternative plans. OSE and RED accounts have a proviso:

> Effects that cannot be satisfactorily quantified or described with available methods, data, and information or that will not leave a material bearing on the decision making process maybe excluded from the OSE (or RED) account.

This proviso would not only eliminate useless material but might also eliminate important material which may be either for or against an alternative plan. The wording is vague, there seems to be no incentive to try and estimate or develop a hypothesis concerning these effects. This statement introduces the idea of the value of information versus the cost of information which will not be discussed here. This proviso may be used to embellish one side of the argument for or against an alternative plan.

Section one also specifies who costs should be allocated to: "Costs are to be allocated only to purposes (a product or use) for which participants in plan implementation have cost-sharing authority unless the plan proposes a change in cost-sharing policy" (Federal Register, 1980). This means that one cannot allocate costs to just

any product or use. The use must have cost-sharing authority. For example, under a certain plan only timber and range have cost-sharing authority. Recreation does not have cost-sharing authority; therefore, no costs may be allocated to recreation. However, this does not exclude the plan from producing recreational uses. Recreation may feasibly cause extra costs to be incurred without having to pay for them. For example, adding an extra mile of road to a plan to reach as trail and charge the extra cost to timber because recreation does not have cost-sharing authority.

Section two, Definitions, defines separable costs, joint costs, alternative costs, and remaining benefits. Separable costs are defined by the Federal Register (1980) as the "reduction in financial cost that would result if that purpose were excluded from the plan." Separable costs include the reductions in the "cost of facilities and activities serving only the excluded purpose" plus reductions in the "cost of facilities and activities serving multiple purposes" (Federal Register 1980). Joint costs are defined as "the total financial costs for a plan minus the sum of separable costs for all purposes" (Federal Register, 1980). A purpose's alternative cost is the "financial cost of achieving the same or equivalent benefits with a single-purpose plan" (Federal Register, 1980). Are the "same or equivalent benefits" stated in the definition of a multiple-purpose plan, or are they the benefits that accrue

to a single purpose within a multiple-purpose plan? I assume they are the benefits that accrue to a single purpose within a multiple-purpose plan.

The benefits of a purpose are defined as either national economic development (NED) benefit or the alternative cost. NED is the contributions to national economic development measured by increase in the value of the national output of goods and services. This seems to be the use of national multipliers as compared to regional multipliers used in RED accounts. The wording is vague here, I am not sure whether the NED measures the benefit from a multiple-purpose or single-purpose plan. I am assuming that NED measures the benefit from a multiple-purpose plan.

The remaining benefit for each purpose is the positive residual when separable costs are subtracted from the NED benefit or the alternative cost. A purpose's benefits are measured by the alternative cost if the alternative cost is less than the NED benefit. The alternative cost then becomes a proxy for measuring benefits. However, alternative cost would only measure the benefits of a single-purpose plan while NED measures the benefits of a multiple-purpose plan.

Section three, Cost Allocation Standard, describes how the joint costs are to be allocated between purposes. The amount allocated to each purpose is the sum of its separable

cost plus a portion of the joint costs. Separable cost/remaining benefit allocates joint costs among purposes in proportion to the remaining benefits. Or joint costs may be allocated in proportion to the use of facilities (Federal Register, 1980). The sum of the allocated costs should not exceed the purpose's alternative cost. This means if the purpose costs more when produced jointly as compared to singly, the purpose should be produced singly. Therefore, the sum of the remaining benefits for each purpose must be greater than or equal to the joint cost of the plan. If a purpose's remaining benefit is 10% of the plan's joint cost then the purpose is allocated 10% of the joint cost. Or, if a purpose uses 10% of the facilities; e.g., a plant, then the purpose is allocated 10% of the plan's joint cost.

Proportional allocation is very arbitrary and makes no economic sense (Herfindall and Kneese, 1974 and Ungar, 1980). This is especially true when using joint costs allocated by proportional use of facility (Herfindall and Kneese, 1974). There are no economic criteria used in determining these proportions; therefore, no meaningful economic interpretation may be made. For example, if there are 10 uses of a facility, each use is allocated 10% of the facility's joint cost. Herfindall and Kneese (1974) defend allocating joint cost in proportion to the remaining benefit: "The appeal of this method is to a certain sense of equity and that it, unlike proportionate use of capacity

(facility), will never make a purpose appear inefficient when in fact it is not." However, Herfindall and Kneese (1974) qualify his statement by stating: "The only way its use might disturb the efficiency of an investment is if the price of the output is based on it, and this causes a significant departure from marginal cost pricing." This describes cases where marginal revenue does not equal output price.

There is one provision: the sum of the allocated costs must not exceed the purpose's alternative cost. This provision will be violated whenever the plan's joint cost exceeds the sum of the remaining benefits. Or if the sum of the remaining benefits exceeds the plan's joint cost, and if the remaining benefits are determined using NED, when NED is larger than the purpose's alternative cost, this provision might again be violated. In this case, the amount allocated to the purpose might exceed its alternative cost and the purpose would appear inefficient in the multiple-purpose plan. However, when the sum of the remaining benefits exceeds the plan's joint cost, and remaining benefits are determined as defined by the Federal Register (1980) then the purpose will always appear efficient when produced using the multiple-purpose plan. If any one purpose, in the multiple-purpose plan is allocated an amount greater than its alternative cost, separable cost/remaining benefit can not be used to allocate costs of that multiple-purpose plan

(Federal Register, 1980). When the provision is violated "joint cost is to be allocated by an alternative method that is judged by the Secretary of a Department or a head of an independent agency to provide a more equitable distribution" (Federal Register, 1980). I interpret this to mean that if separable cost/remaining benefit does not make the multiple-purpose plan seem efficient, across all purposes, an alternative allocation system should be used to make the multiple-purpose plan appear efficient.

The final section is Allocation of Constituent Cost. This section states that costs such as land cost, construction costs, and operation and maintenance costs "specified" in cost-sharing policy are to be allocated among purposes (Federal Register 1980). If such a cost is not "specified" in relevant cost-sharing policies then it will not be allocated among purposes. If it is not allocated among purposes it must be assigned to a purpose. I would be feasible to assign large portions of an investment cost to any single purpose even if these costs were joint.

Arithmetic Example

I will not examine allocating costs using proportional use of facility in depth. Herfindall and Kneese (1974) and Ungar (1980) give examples of why this allocation method makes no economic sense.

The joint cost may be allocated among purposes in proportion to remaining benefit. The main difference between this method of allocation and the previous method is determining the proportions. Young et al. (1980) use a more complex arithmetic example to critique separable cost/remaining benefit; however, I will use a simple example. The conclusions I reach are the same as Young et al. (1980). I will examine three different cases. Case one will show that when the plan's joint cost is less than the sum of the remaining benefits, all purposes appear efficient and the manager should produce jointly. Case two will show that when the plan's joint cost is equal to the sum of the remaining benefits the manager is indifferent between producing the purposes jointly or singly. Case three will show that when the plan's joint cost is greater than the sum of the remaining benefits all purposes appear inefficient and the manager should reject the multi-purpose plan.

A multiple-purpose plan has three purposes: A, B, and C. The purposes' alternative costs are 30, 40, and 50 respectively. I will assume the alternative cost is less than the NED. The purposes' separable costs are 5, 10, and 15 respectively. Each purpose's remaining benefit is 25, 30, and 35, respectively. The sum of the remaining benefits is 90. Purpose A is allocated 28% of the plan's joint cost; i.e., 25/90=0.28. Purpose B is allocated 33% of the plan's joint cost; i.e., 30/90=0.33. Purpose C is allocated 39% of

the plan's joint cost 35/90=0.39. The plan's joint cost is determined by subtracting the sum of the separable costs from the plan's total financial cost. The total amount allocated to each purpose is its proportions of the plan's joint cost plus its separable cost.

Case one is when the plan's joint cost is less than the sum of the remaining benefit: The plan's joint cost is 70 and the sum of the remaining benefits is 90. Purpose A is allocated $19.60 of the plan's joint cost; i.e., 0.28(70)=19.60. Purpose B is allocated $23.10 of the plan's joint cost; i.e., 0.33(70)=23.10. Finally, purpose C is allocated $27.30 of the plan's joint cost; i.e., 0.39(70)=27.30. The total amount allocated to purposes A, B, and C is a proportion of the joint cost plus each purpose's separable cost or $24.60, $33.10, and $42.30, respectively. The total amount allocated to each purpose is less than each purpose's alternative cost. Therefore, it is more efficient to use the multiple-purpose plan then produce each purpose separately.

Case two is when the plan's joint cost is equal to the sum of the remaining benefits: The plan's joint cost and the sum of the remaining benefits both equal 90. Purpose A is allocated $25 of the plan's joint cost; i.e., 0.28(90)=25. Purpose B is allocated $30 of the plan's joint cost, i.e., 0.33(90)=30. Purpose C is allocated $35 of the plan's joint cost; i.e., 0.39(90)=35. The total amount

allocated to purposes A, B and C are \$30, \$40, and \$50, respectively. The total amount allocated to each purpose is equal to each purpose's alternative cost. The multiple-purpose plan is still efficient; however, a decision maker would be indifferent between choosing the multiple-purpose plan or three single-purpose plans.

The final case is when the plan's joint cost is greater than the sum of the remaining benefits: The joint cost is equal to \$91 and the sum of the remaining benefits is equal to \$90. Purpose A is allocated \$25.28 of the plan's joint cost; i.e., 0.28(90)=25.28. Purpose B is allocated \$30.33 of the plan's joint cost; i.e., 0.33(91)=30.33. Purpose C is allocated \$35.39 of the plan's joint cost; i.e., 0.39(91)=35.39. The total amount allocated to purposes A, B, and C are \$30.28, \$40.33, and \$50.39, respectively. The multiple-purpose plan is no longer efficient. The amount of costs allocated to each purpose is greater than each purpose's alternative cost. In addition, each purpose was shown to be inefficient.

Conclusion

In conclusion, separable cost/remaining benefit is an all or nothing deal. If the plan's joint cost is less than or equal to the sum of the remaining benefits, the multiple-purpose plan is efficient and each purpose's benefits are greater than or equal to their costs. However,

just the opposite is true when the plan's joint cost is greater than the sum of the remaining benefits. In addition, separable cost/remaining benefit does not allow for comparing subgroup efficiency. For example, in order for A and B to be produced within multiple-purpose plan, the costs allocated to A and B must be less than the cost of producing A and B singly. Furthermore, for A and B to remain in the multiple-purpose plan, the cost allocated to A and B must be less than the cost of producing A and B jointly in a subgroup. These conclusions are consistent with those of Young et al. (1980).

Separable cost/remaining benefit is a fancy name for proportionally allocating joint costs. From an accounting standpoint the technique works. However, from an economic view proportional allocation is very arbitrary. There are other more sophisticated methods of allocating joint costs such as Stigler (1952), Steiner (1957), Pfouts (1961), Hirshleifer (1958), Weil (1968), Deinsetz (1970 and 1973), Lochman and Whinston (1971), Nicholls and Saad (1974), Moriarty (1975), and Halmen et al. (1977 and 1980). However, there is no reference of these techniques applied to forestry problems.